

Hiroshi ARITA, Ibaraki, JAPAN;  
Masahiro WATANABE, Ibaraki, JAPAN;  
Junichi MAKINO, Ibaraki, JAPAN;  
Tadashi SENDA, Tokyo, JAPAN;  
Youichi OHSHITA, Ibaraki, JAPAN;  
Genichiro ICHIHARI, Tokyo, JAPAN;  
Naoyuki YAMADA, Ibaraki, JAPAN;  
Tetsuo HORIUCHI, Ibaraki, JAPAN;  
Chihiro FUKUI, Ibaraki, JAPAN;  
Hiroyuki KUDO, Tokyo, JAPAN.

# United States Patent Application

**Title**

# ENERGY AND POWER INTERCHANGE SYSTEM AND ITS METHOD

**Inventors**

Hiroshi ARITA,  
Masahiro WATANABE,  
Junichi MAKINO,  
Tadashi SENDA,  
Youichi OHSHITA,  
Genichiro ICHIHARI,  
Naoyuki YAMADA,  
Tetsuo HORIUCHI,  
Chihiro FUKUI,  
Hiroyuki KUDO.

Title of the Invention

Energy and power interchange system and its method

Background of the Invention

5 This invention relates to an energy and power interchange system and method for interchanging power in a wide area extending over a plurality of countries, and more particularly <sup>to an</sup> ~~the~~ energy and power interchange system for interchanging and its method which take  
10 into account the time difference and the regional difference.

With respect to the power demand and supply, along with the economic development of respective regions, the absolute value of the power demand is  
15 increasing and the peak load is also increasing, while the load factor is lowering year by year. To cope with this phenomenon, electric utilities are requested to build power plants having power source capacity which can make up for this peak load. Recently, the  
20 regions which cannot respond to the rapid power demand adopt measures to supply electric power to the regional load by means of distributed power sources such as IPP (abbreviation of independent power producers) which can be developed in a short period.

25 To meet the request to increase the facilities of electric power <sup>systems</sup> ~~system~~, the construction of power plants, transmission lines and substations which can transmit electric power <sup>is increasing</sup> ~~is~~ corresponding to the increasing load. In the vicinity of urban cities,  
30 however, it is difficult to obtain a site for nuclear power, and hydraulic power <sup>sources are</sup> ~~source is~~ remote from the place of demand in general. On the other hand, recently, in terms of environmental problems and the

like, it is getting harder and harder to secure sites which are available for power plants so that the problem that the construction of new power plants is difficult has become apparent.

5 As one of measures to solve this problem, for increasing the serviceability of existing power plants, the efficient system operation between countries has been considered. To this end, the technology which can increase the stability of the existing systems and  
10 strengthen the transmission ability becomes necessary, and as tasks for the control and operation of the system, maintenance and administration of the fluctuation of voltage and frequency by restricting the fluctuation of the system and realization of  
15 reasonable electric power distribution through the power interchange or transmission under consignment are named. To restrict the fluctuation of the system, the control of electric generators and the control of load are available and it is necessary to strengthen  
20 the system interconnection through the alternating current or the direct current.

As a plan for multinational system interconnection, CIGRE Keynote Address (Paris, August 28, 1994 ) has been proposed. In this literature, as  
25 an Africa - Europe system interconnection, a system ~~inter connection~~ <sup>the</sup> around Mediterranean Sea and an ~~inter connection~~ <sup>the</sup> on the African Continent are introduced. For example, with respect to the system interconnection on the African Continent, as effects  
30 of application, (1) interconnection of peak load between winter season and summer season and (2) reduction of daily system peak load considering 4 hours time difference between the east and the west

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are described. This literature, however, merely  
suggests the development of ~~the Zaire~~<sup>Zaire</sup> located at the  
center of Africa and the construction of <sup>a</sup>hydro  
electric power plant and its estimated power of 40 GW  
5 (100 GW in future) and fails to describe how the plan  
is realized with any concrete means.

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To realize the multinational power interchange  
actually, it is essential to provide concrete means to  
interconnect <sup>a country's</sup> own power system with the power systems  
10 of other countries corresponding to the features of  
power systems of respective countries and differences  
of power systems among respective countries.  
Furthermore, it is necessary to decide the operation  
mode corresponding to the situations of respective  
15 countries.

#### Summary of the Invention

It is the first object of the present invention  
to obtain economic effects such as reduction of  
electric rates by operating the power facilities of a  
20 plurality of countries in a comprehensive manner.

It is the second object of the present invention  
to provide a stable supply of power by operating the  
power facilities of a plurality of countries in a  
comprehensive manner.

25 It is the third object of the present invention  
to obtain social effects such as reduction of  
environmental load and the regional gap by operating  
the power facilities of a plurality of countries in a  
comprehensive manner.

30 To achieve the above objects, the energy and  
power interchange system of the present invention  
comprises a system including energy generating means  
which generates transmittable energy using an energy

a source, an energy path which transmits energy  
a generated by the energy generating means, ~~a~~ measuring  
equipment which is mounted on the energy path for  
measuring an amount of energy which is transmitted  
5 through the energy path, and a system which consumes  
a energy supplied by way of the energy path, and ~~the~~  
a ~~energy and~~ such a power interchange system is  
characterized in that the energy sources used by the  
energy generating means and the generated energy  
10 amount are controlled in response to the energy amount  
measured by the measuring equipment.

Furthermore, in an energy and power interchange  
system which comprises a first system including power  
generating facilities, a second system in foreign  
15 countries having power generating facilities, an  
energy path constructed by a direct current  
transmission system which interconnects the first  
system and the second system, and ~~a~~ measuring  
equipment which is mounted on the energy path and  
20 measures an energy amount transmitted through the  
energy path, the system is characterized in that  
control parameters of the first and the second systems  
are changed or the transmitting direction of energy is  
decided in response to the energy amount measured by  
25 the measuring equipment.

Furthermore, in an energy and power interchange  
system which comprises an energy path constituted by a  
direct current transmission system which interconnects  
systems of at least three foreign countries having  
30 power generating facilities and ~~a~~ measuring equipment  
which is mounted on the energy path and measures the  
energy amount transmitted through the energy path, the  
system is characterized in that the control parameters

of the systems of at least three countries are changed or the transmitting direction of energy is decided in response to the energy amount measured by the measuring equipment.

5 Furthermore, the energy and power interchange system includes ~~an~~ interconnection adjustment equipment which transmits converted values to respective systems in response to information measured by the measuring equipment, wherein the converted  
10 values are converted values of expenses including energy generating expense and energy transmission expense or converted values of environmental load including generated carbon oxide gas. Furthermore, the energy and power interchange system includes an  
15 interchange administration equipment which carries out the settlement, the conclusion of contract or the interchange control using the converted values transmitted from the interconnection adjustment equipment. Furthermore, a power storage equipment is  
20 installed in at least one of the systems and the input and output of the power storage equipment is controlled in response to the change of power flow rate between systems. Furthermore, respective systems  
25 are located at countries which differ in circulating currency and they convert to the preliminarily decided currency unit or carry out such a conversion based on the information on the exchange rate, or the above-mentioned respective systems are located in countries which differ in languages and information is  
30 transmitted by way of translating machines. Furthermore, the system comprises a system which includes many thermal power facilities and a system which include many hydro electric power facilities,

wherein the generated power amount is controlled such  
that overall fuel consumption ~~amount~~ of the system  
which includes many thermal power facilities is lower  
than the predetermined value and energy is transmitted  
from the system which includes many hydro electric  
power facilities. Furthermore, the system comprises a  
system having electric power of good quality and a  
system having electric power of poor quality, and the  
system is controlled such that the power flow flows  
from the system of good electric power to the system  
of poor electric power. Furthermore, the systems are  
located in countries having at least 2 hours time  
difference and the energy transmitted from one system  
to another system is controlled using demand  
estimation data of respective systems. Furthermore, an  
alternating current/direct current converter may be  
provided between the system and the energy path, and as  
information transmission means for transmitting  
information to control the alternating current/direct  
current converter, at least one of satellite  
communication facilities, optical communication  
facilities, microwave communication facilities and  
telephone circuit communication facilities <sup>are</sup> ~~is~~ provided.  
The information communication means is provided with  
delay timers. Furthermore, the information includes  
information on the system, or information to which  
time information detected by a transmission time  
difference detector for detecting time difference for  
information transmission is added, or the interchanged  
electric energy, the restriction on the interchanged  
electric energy, or operation information on a direct  
current power transmission system. A consideration to



the settlement, conclusion of contract or interchange control by the above-mentioned interchange administration equipment may be at least one of the CO<sub>2</sub> emission right which concerns with CO<sub>2</sub> emission utilities, fuel, electrical energy or money.

Furthermore, the energy and power interchange system is provided with ~~a~~ power interchange control equipment, and such ~~a~~ power interchange control equipment decides the operating condition of the generator, or the operating condition of the power storage equipment, or the interchanged electrical energy between the alternating current systems using at least one of interchangeable electrical energy, the electrical energy, load of respective alternating current systems, generated energy, <sup>and</sup> emergency power source. Furthermore, the interchange power command value is decided using at least one of demand information, power generating information, exchange rate information, power generating cost information and power transmission information. Furthermore, using at least one of the power cost, the power generating and transmission cost, CO<sub>2</sub> emission amount, load balancing index, demand and supply balance index, or power supply reliability index of respective countries or regions or of every hour~~s~~ or every season~~s~~ is formed as an object function, <sup>and</sup> the interchanging power command value is decided based on the calculation result of a calculation processing equipment which executes an optimization calculation.

Furthermore, the energy and power interchanging method is characterized in that a first system which is provided with power generating facilities and a second system in a foreign country which is provided with power generating facilities are interconnected by

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an energy path constituted by a direct current power  
transmission system, and the transmitting energy is  
measured by a measuring equipment mounted on the  
energy path. ~~and the~~ <sup>The</sup> Control parameters of the first  
5 system or the second system are changed or the energy  
transmitting direction is decided in response to the  
energy amount measured by the measuring equipment.

Furthermore, converted values of the cost  
including the energy generating cost and the energy  
10 transmission cost and the converted values of the  
environmental load including generated carbon oxide  
gas are obtained based on information measured by the  
measuring equipment and the settlement, the conclusion  
of contract or the interchange control is carried out  
15 using the converted values.

Brief Description of the Drawings

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Fig. 1 is a view showing <sup>the</sup> Asia Pacific Rim  
Electricity Cooperation (APREC) according to one  
embodiment of the present invention.

20 Fig. 2 is a perspective view showing an example  
of installing a pipe line and a power transmission  
line using the same route.

Fig. 3 is a block diagram showing the  
interconnections by way of measuring modules.

25 Fig. 4 is a block diagram showing the  
interconnections to which CO<sub>2</sub> measuring modules are  
applied.

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Fig. 5 is a flow chart showing one <sup>a</sup> example of <sub>A</sub>  
method for carrying out the settlement of transaction  
30 of energy between systems

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Fig. 6 is a block diagram showing one <sup>a</sup> example of <sub>A</sub>  
method for carrying out the transaction of energy  
between systems.

Fig. 7 is a graph showing the change of electricity consumption of one day in summer season.

Fig. 8 is a graph showing the change of electricity consumption in respective months.

5 Fig. 9 is a block diagram showing one embodiment which interconnects a plurality of alternating current systems by means of direct current power transmission systems.

10 Fig. 10 is a block diagram showing control of interconnection lines and information transmitting means.

Fig. 11 is a block diagram showing a plurality of systems which are interconnected by direct power transmission systems.

15 Fig. 12 is a block diagram which shows a plurality of alternating current systems which are interconnected by direct current power transmission systems.

20 Fig. 13 is a flow chart showing the manner for maintaining the power supply reliability in the systems shown in Fig. 12.

Fig. 14 is a flow chart showing the method which purchases electricity from other systems.

25 Fig. 15 is a block diagram showing the interchanged power control by the direct current of direct current interconnection with a remote site.

Fig. 16 is a block diagram which measures the delay of transmission path shown in Fig. 15.

Detailed Description of the Preferred Embodiments

30 The one embodiment of the present invention is explained in conjunction with Fig. 1 to Fig. 16.

a Fig. 1 shows systems in countries around Asia and Pacific rim and interconnection lines of an energy and the

power interchange system which connect a plurality of countries in the region. Main systems are the Canada system, the America system, the Russia system, the Far East system, the Japan system, the China system, the Vietnam system, the Thailand system, the Malaysia system, the Indonesia system, the Australia system and the South Pole system.

In Fig. 1, as shown in a solid line, the interconnection line 1 interconnects Russia and Hokkaido of Japan to transmit power therebetween. The interconnection line 2 interconnects Russia and China to transmit power therebetween. China's electrical energy facilities capacity at the end of 1996 <sup>are</sup> ~~is~~ 236 GW which is larger than <sup>the</sup> ~~a~~ 227 GW of Japan. Namely, China is the second in the world in terms of electrical energy facilities capacity and it consists of 76 % of thermal power, 23 % of hydro electric power and 1 % of nuclear power. In the ninth five year program started from 1996, it is planned that electrical energy facilities will be increased by 17 GW at average every year until 2000 and the system of power transmission and distribution will be strengthened. As envisaged from the project of Sanxia hydro electric energy facilities, although China is positively advancing its development, there still remains a possibility that China will suffer from <sup>a</sup> ~~the~~ shortage of electric power for her electric power demand.

The interconnection line 3 interconnects South Korea and Japan to transmit power therebetween. The interconnection line 4 interconnects South Korea and China to transmit power therebetween. The interconnection line 5 interconnects ~~the~~ Vietnam and China to transmit power therebetween. The

a interconnection lines 6, 7, 8 respectively  
interconnect Malaysia, Myanmar, Laos and Thailand to  
transmit power to <sup>these</sup> respective countries.

5 The interconnection line 9 interconnects Sumatra  
and Java to transmit power therebetween. The  
interconnection line 10 interconnects Malaysia and  
Philippine to transmit power therebetween. The  
interconnection line 11 interconnects Canada and  
Russia to transmit power therebetween. The  
10 interconnecting 12 interconnects Australia and  
Indonesia to transmit power therebetween. Since  
Australia is <sup>a</sup> ~~the~~ vast continent, there is ~~a~~ sufficient  
space which can be developed as sites for generating  
power facilities so that there is a great possibility  
15 that Australia will be chosen as the site for an  
electric source~~s~~ made of non-fossil fuel.  
Besides <sup>the</sup> these interconnections, interconnections  
between <sup>a</sup> following countries are considered, e.g. Laos  
and China, Myanmar and China, Cambodia and Thailand,  
20 Cambodia and Vietnam, Malaysia and Indonesia, Myanmar  
and India, Myanmar and Bangladesh, India and China,  
Canada and Russia, Australia and New Zealand, America  
and Mexico, Mexico and Caribbean countries, Caribbean  
countries and South American countries, South America  
and <sup>the</sup> ~~the~~ Antarctic Continent, <sup>the</sup> ~~the~~ Antarctic Continent and  
25 Australia and <sup>the</sup> ~~the~~ Antarctic Continent and New Zealand.

a The distance of respective interconnection lines  
is some hundreds km - some thousands km and their  
power transmission capacity is some GW - some tens GW,  
30 thus enabling the power interchange in a wide area.

a The respective alternating current power systems  
which are constructed in the above manner are  
interconnected by ~~the~~ direct current power

a transmission systems. For example, <sup>the</sup> Australia system  
a and <sup>the</sup> Indonesia system are interconnected with the  
interconnection 12 which is a direct current power  
transmission route. Japan's 50 Hz system is  
a 5 interconnected with <sup>the</sup> Far East system and <sup>the</sup> Russia system  
by way of Hokkaido and Sakhalin with the  
interconnection 1 which is a direct current power  
transmission system. Japan's 60 Hz system is  
a interconnected with <sup>the</sup> China system and <sup>the</sup> Far East system  
10 with a direct current power transmission system.  
Furthermore, Canada system is connected with Far East  
system and Russia system by way of Alaska and the  
Bering Strait with the interconnection 11 which is a  
direct current power transmission system. In this  
15 manner, the alternating systems in respective regions  
of the Asia Pacific rim shown in Fig. 1 are  
interconnected with each other with the direct current  
power transmission systems. Such an interconnection  
20 enables ~~the~~ efficient power transmission over a long  
distance.

a A power transmission line of each direct current  
power transmission system is made <sup>of</sup> ~~or~~ either a cable or  
an overhead line. At a portion where the alternating  
25 current system of each region is connected with the  
direct current power transmission system, an  
alternating current/direct current converter is  
installed. The direct current power transmission  
system adopts either 1 : 1 interconnection which makes  
30 two alternating current systems connected with a pair  
of alternating current/direct current converter by a  
direct current line or direct current multiple  
terminals in which alternating current /direct current

a converters are respectively installed in more than two alternating current systems, and these are connected with each other by branched direct current lines.

5 In installing the direct current power transmission lines using the cable, they are installed on the bottom of the sea, or installed underground, or installed on the surface of the ground. Furthermore, if the regions are already connected with each other by pipe lines such as gas pipelines or the  
10 installation of the pipelines is planned, the direct current power transmission lines are installed on the same route as these pipelines. In this case, the direct current power transmission lines share supporting structures with the pipelines or the direct  
15 current power transmission cables can be fixedly secured to the pipe lines. Furthermore, the cable may be installed within the pipeline.

20 In Fig. 2, a case that a pipeline 81 and a power transmission cable 82 are installed on the same route is exemplified. Inside a supporting structure 83, the pipeline 81 and the power transmission cable 82 are installed and they are fixedly secured to the ground by means of the supporting structure 83. The power  
25 transmission cable 82 is fixedly secured to the pipeline 81 by means of a support 84. In this manner, the power transmission cable 82 shares the route and the supporting with the pipeline 81 so that the reduction of installation cost, the reduction of supporting structure cost and the reduction of  
30 monitoring equipment cost can be achieved, thus enabling the reduction of construction cost.

a Although ~~the~~ gas pipelines are considered here, similar installation methods are applicable if other

a distribution facilities such as petroleum pipelines  
are available. Furthermore, although the cables are  
explained considering that <sup>they are</sup> ~~it is~~ used for the direct  
current transmission, alternating current cables are  
5 applicable if the alternating current interconnection  
is used. A gas insulation line ( abbreviated as GIL )  
a which installs a conductive body in a pipe and <sup>applies</sup> ~~apply~~ a  
gas insulation is also applicable. Here, as the power  
generating facilities, any facilities which generate  
10 electric power using coal, natural gas, uranium, solar  
beams, and wastes can be employed.

In this manner, since the electric power systems  
of respective regions have their regionality and  
characteristics, it is rational to construct the  
15 systems in respective regions depending on respective  
regions, and interconnections are carried out by  
connecting regional ~~system~~ <sup>systems</sup> of respective regions by  
transmission facilities. Accordingly, since  
interconnections ~~includes interconnection~~ <sup>include interconnections</sup> between  
20 different systems or ~~interconnection~~ <sup>interconnections</sup> between systems  
which are remote from each other in terms of distance,  
the systems are interconnected by direct current  
interconnection facilities. Furthermore, in a case  
that there is no substantial difference in electric  
25 characteristics and the distance between the systems  
is short, the systems may be interconnected by  
alternating current power transmission facilities.

In countries which are arranged along the coast  
of the Pacific Ocean, as shown in Fig. 1, different  
30 languages are used. At present, English, French,  
Spanish, Portuguese, Russian, Chinese, Malay, Japanese  
and the like are used. Furthermore, since they differ  
in circulating currency, as a settlement method of



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can be applied.

In response to <sup>the</sup> transmission amount of energy of  
respective systems which are detected by the measuring  
equipment 25, 26, 27, 28, 29, 2a, ~~the~~ parameters such  
5 as the generating power amount of respective systems  
or the control amount of direct current converters are  
changed. Furthermore, in response to the transmitting  
amount of energy, items having values such as  
information or goods are transacted between systems,  
10 or contracts are concluded or changed. Furthermore,  
depending on the transmitting amount of energy of  
respective systems, the construction of respective  
systems is changed.

For example, the information on energy amount  
15 from the measuring equipment 26, 27, 2a is transmitted  
to ~~an~~ interconnection adjustment equipment 2i and  
based on the information, the interconnection  
adjustment equipment 2i ~~inform~~ <sup>informs</sup> the systems 21, 23, 24  
which are relevant with the transmission of energy of  
20 the information on energy or items having values  
equivalent to the transmission of energy, for example  
electric rates, other alternative energy or  
information on rights such as CO<sub>2</sub> emission rights.  
Based on <sup>this</sup> ~~these~~ information, respective systems  
25 transact price corresponding to the transmission  
amount of energy.

Such a transaction is carried out between two  
systems. For example, when the electric power is  
transmitted from the system 21 to the system 22 by way  
30 of the direct current power transmission system, the  
measuring equipment 25 measures the interchanged  
electric energy and transmits its information to ~~an~~  
interconnection adjustment equipment 2h. The

interconnection adjustment equipment 2h transmits  
information on the electric energy moved to the  
systems 21, 22 which are relevant with the movement of  
the electric energy, or transmits other energy amounts  
5 corresponding to the electric energy or right amount  
such as the CO<sub>2</sub> emission right. In accordance with  
this information, the system 22 pays<sup>a</sup> reward to the  
system 21 for the accepted electric energy.

Although the system shown in Fig. 4 is  
10 constructed in the same manner as that of Fig. 3, in  
the system shown in Fig. 4, CO<sub>2</sub> administration  
equipment 3j, 3k, 3l, 3m which <sup>measures</sup> ~~measure~~ and  
<sup>administrate</sup> ~~administrate~~ the CO<sub>2</sub> discharge amount produced by  
generation of power at respective systems <sup>is</sup> ~~are~~  
15 installed in respective systems. The interconnection  
adjustment equipment 2h, 2i <sup>receives</sup> ~~receive~~ the information on  
the energy amount transacted between systems from the  
measuring equipment 25, 26, 27, 28, 29, 2a and  
<sup>transmits</sup> ~~transmit~~ CO<sub>2</sub> emission <sup>amounts</sup> ~~amount~~ for generating energy  
20 moved in response to the information or considered to  
be generated for transmitting the energy to systems  
which are concerned with the transmitting and  
receiving of the energy.

For example, when the electric power is supplied  
25 from the system 21 to the system 22 by way of the  
direct current power transmission system, CO<sub>2</sub> is  
emitted in air from a power plant in the system 21 for  
generating electric power, <sup>and</sup> the emitted CO<sub>2</sub> amount is  
grasped by ~~an~~ administration equipment 3j. Namely, at  
30 the administration equipment, the CO<sub>2</sub> amount generated  
in the system 21 is counted and then is integrated.  
Furthermore, the information on the electric energy  
from the system 21 to system 22 which is measured by

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emission burden amount. When the settlement is made by the fuel, the interchanged energy amount is converted to the fuel such as petroleum or gas. When the settlement is made by the electricity energy, the interchanged energy amount is converted to electric energy. When the settlement is made by money, the interchanged energy is converted to the preliminarily decided currency unit. When the settlement is made by money, conversion is made using the information on real time exchange rate or preliminarily decided exchange rate. The conversion result obtained in the above manner is transmitted to the system which interchanged the energy and delivers right or energy such as petroleum or gas or carries out the conclusion of a contract in accordance with the method of settlement. When the difference exists in terms of unit price of electricity energy including the power transmission loss, the interchange which corresponds to the difference of unit price is carried out so as to make both the buyer and purchaser have ~~the~~ economic merit. As a concrete method for this end, under a total operator as an arbitrator, the buyer and the purchaser carry out the interchange in a free market style.

In Fig. 6, a case in which , for example, Canada system 51, Far East system 22, China system 23 are interconnected by power transmission systems is exemplified. The systems are respectively interconnected by energy paths 56, 57 and measuring equipment 54, 55 are mounted on these energy paths for measuring the energy amount which is moved between the alternating current systems. The systems are respectively provided with interchange administration

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the measured value of interchanged electric power from the measuring equipment 54, 55 and transmits the information on the settlement to the interchange administration equipment 5a, 5b, 5c of respective alternating current systems. In response to the transmitted information, the interchange administration equipment of respective systems carry out the settlement on the interchange such as the electric rates or the system use fee respectively.

The second method is a method in which the interchange contract is concluded between neighboring systems respectively. For example, the system 23 concludes a contract to receive the necessary power interchange from the neighboring system 22 and the system 22 concludes a contract to receive the necessary power interchange from the neighboring system 51 so that the power interchange from the system 51 to the system 23 becomes possible. In this case, the contract may be concluded between the system 51 and the system 22 and between the system 22 and the system 23. This method corresponds to a case of the first method in which no other system is interposed in the interchange path. In this second method, the interchange control and the settlement can be carried out in the same steps as those of the first method.

In the example shown in Fig. 6, making use of the hydro power of Canada, the generation amount of CO<sub>2</sub> by the thermal power generation of the same capacity in China can be reduced so that it can contribute to the prevention of warming of the earth. Furthermore, <sup>because</sup> there is approximately eight hours time difference between Canada and China, lowering of system peak load can be realized making use of the difference of power

transmission time.

Fig. 7 shows the change of electricity consumption condition of one day in summer season. The example shown in Fig. 7 is the electric power system in Japan and a curve 61 indicates the change of electricity consumption in 1995. The electricity consumption increases rapidly from approximately 6 o'clock when people usually get up. Although the electricity consumption drops temporarily at 12 o'clock or at lunch break, it again increases with the use of air conditioners for cooling from 13 o'clock and reaches approximately 170 GW around 15 o'clock and thereafter sharply drops. The electricity energy demand is increasing year by year and it is estimated that the system peak load will reach 200 GW as shown with a curve 62. As a measure to cope with this situation, for example, at the time of system peak load during three hours in the afternoon as shown with a symbol 63, if the electric power system of Japan receives the power interchange from the system which has the time difference, the system peak load of Japan can be reduced by approximately 10 GW. Furthermore, to reduce the system peak load of Japan by approximately five GW, the time difference of approximately 2 hours is sufficient so that, for example, the time difference of 2 hours between Bangkok and Japan can be <sup>employed</sup> ~~made use of~~.

In this manner, by interchanging the electric power with less transmission loss because of the short transmission distance from close regions of at least 1 - 2 hours time difference at the time of system peak load, the system peak load during 1 - 2 hours when the electric energy demand becomes high can be reduced.



Furthermore, there is 6 hours time difference between Japan and Anchorage so that the power interchange can be carried out sufficiently. Still furthermore, <sup>at</sup> 15 o'clock which shows the system peak load in Japan, Vancouver <sup>Los Angeles</sup> of Canada, Los Angeles, and San Francisco <sup>of America</sup> are at 22 o'clock at night so that the power change between daytime and nighttime is effectively <sup>employed</sup> ~~made use of~~. When New York <sup>on the</sup> ~~of the~~ eastern coast of America is 1 o'clock <sup>a.m.</sup> ~~at midnight~~, an excess amount of its electric power at night can be effectively interchanged to <sup>the</sup> Far East system, China system, Japan system, Philippines system, Vietnam system, Thailand system, Malaysia system, Indonesia system, and Australia system of <sup>the</sup> Asian region.

In this manner, although the transmission loss is great, the power transmission from <sup>a</sup> ~~the~~ relatively remote place which <sup>has reversed</sup> ~~reverses the~~ daytime and nighttime can interchange <sup>midnight</sup> ~~the midnight~~ cheap electric power for a relatively long time so that the daily load factor can be improved and pumped power loss can be reduced.

In the actual operation, using the estimated data on electric energy demand of at least two points which differ in the system peak load at daytime, the interconnecting operation between electric power systems including these points is carried out such that the excess electric power which exceeds given electric power at either ~~one~~ point is transmitted to the other point.

Fig. 8 is a view showing the change of monthly electricity consumption ~~condition of electricity~~. As shown in Fig. 8, a curve 71 shows the transition of electricity consumption of Japan in 1995. Although the electricity consumption reaches the system peak

load of approximately 170 GW in August in summer  
season, the electricity consumption considerably drops  
in winter season ~~since~~<sup>after</sup> October. Accordingly, to the  
electric power system which has its system peak load  
5 after October as shown in a curve 72, approximately 10  
GW of electric power can be interchanged as ~~an~~ excess  
electric power as depicted by a symbol 73. For example,  
since there is a difference in season between the  
northern hemisphere and the southern hemisphere, the  
10 power interchange can be carried out making use of  
this difference of season.

In this manner, between the southern and northern  
regions which differ in season such as summer and  
winter, the power interchange of a long period can be  
15 carried out with each season as a unit so that the  
annual load factor can be improved and the base power  
sources amount can be more economical.

In the actual operation, using the estimated data  
on electric energy demand of at least two points which  
20 differ in the system peak load in season, the  
interconnecting operation between electric power  
systems including these points is carried out such  
that the excess electric power which exceeds given  
electric power at either ~~one~~ point is transmitted to  
25 the other point.

Furthermore, as an environment of the power  
generating plants, there are systems which include  
many thermal power plants and systems which include  
many hydro electric power plants. By interconnecting  
30 the system which includes many thermal power plants  
and the system which includes many hydro electric  
power plants, wherein the system which includes many  
thermal plants ~~is a~~<sup>uses</sup> coal thermal power ~~plant~~<sup>plants</sup>, the

power generating facilities in respective electric power systems can be operated such that the total fuel consumption in a predetermined period becomes below a predetermined value to restrict the generation of CO<sub>2</sub> for example. In this case, when the shortage of electric power is expected, an output increase command of the hydro electric power generation of the interconnected system can be requested in advance. With such a control, the generation amount of CO<sub>2</sub> caused by the thermal power generation can be reduced, thus contributing to the prevention of warming of the earth.

Furthermore, electric power sources such as undeveloped hydro power in areas which electric energy demand is small or nuclear power which generate the least amount of earth warming gas such as undeveloped hydro power in areas <sup>where</sup> ~~which~~ electric energy demand is small or nuclear power may preferably <sup>be</sup> ~~be~~ developed, and they may be interchanged through the interconnection lines so as to use them as electric power sources which substitutes <sup>for</sup> ~~the~~ thermal power in areas where the electric energy demand is high, thus reducing the environmental load.

Furthermore, the two-way utilization of the electric power is also considered. As explained previously with respect to the power interchange making use of the time difference and the power interchange making use of the difference of season, <sup>respectively</sup> ~~respective~~ generated powers <sup>is</sup> ~~are~~ fully <sup>employed,</sup> ~~made use of~~ and through the power interchange between different countries, the working rate of the facilities is increased so that cheap electric power becomes available. There are fluctuating factors with respect

When an accident occurs in the power system, the electric power is urgently supplied from the area having no trouble so as to prevent a large-scale power failure or a long time power failure. Due to such a

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measure, the reliability of power supply is enhanced and a reserve electric energy supply which becomes necessary at the time of occurrence of accident can be minimized, thus providing an economic effect. As

a  
5 concrete measures, the systems are connected by direct current interconnecting equipment such that the occurrence of the accident is automatically detected upon drastic lowering of the frequency of the system, and for automatically flowing the electric power to  
10 the interconnection line in response to the degree of the accident, information on the condition of the accident and the condition of the system before the occurrence of the accident are gathered at a place where an overall operation is carried out and an  
15 overall judgement is made by an automatic control equipment, thus facilitating the control of the power flow. In this case, autonomous distributed control is carried out.

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a  
When ~~the~~<sup>a</sup> drought occurs because of ~~the~~<sup>the</sup> El Nino phenomenon  
20 and the normal hydro electric power amount is drastically reduced, the system can receive the power interchange from countries and regions which have sufficient electric power sources.

Since the system of this embodiment interconnects  
25 the systems of regions which largely differ in electric characteristics and are geographically located randomly and they also differ in their needs for the operation of systems, their interests may conflict. To make this system perform its expected  
30 effects or advantages, an overall operation control center is necessary, wherein the center is an organization which observes the system as a whole and totally operates and controls the system. This

overall operation control center gathers information necessary for the operation of the system such as the power flow conditions of respective power interconnecting facilities, information necessary for knowing the excess transmission power of interchanged power flow in respective systems, the unit price of interchanged power in respective regions, the transmission loss fee corresponding to the interchange distance, the excess generated power in respective regions, request for receiving of electric power and its degree of urgency, the presence of the accident in the systems and carry out the the effective operation with the aid of an automatic operation support system.

Furthermore, the utilization of power interchange to countries which differ in the quality of the electric power is considered. To the region of low electric power quality where the fluctuation of frequency is large even during the normal operation time, for example, the power flow which can improve the fluctuation of the frequency is flown, thus improving the characteristics of the system. Accordingly, the construction of an advanced cutting-edge industry becomes possible so that the economy is activated.

Fig. 9 shows one embodiment which interconnects a plurality of systems with direct current power transmission systems. Alternating current systems 91, 92 are interconnected by a direct current power transmission system 95 which is provided with an alternating current/direct current converters 9a, 9b and a direct current power transmission line 9e. Alternating current systems 92, 93 are interconnected by a direct current power transmission system 96 which

a is provided with an alternating current/direct current converters 9c, 9d and a direct current power transmission line 9f.

a  
5 ~~A power~~<sup>Power</sup> storage equipment 94 is mounted on the alternating current system 92. In this manner, with the power storage equipment 94 mounted on the alternating current system 92, for example, when any system trouble occurs in the alternating current system 91 or when the interconnection power flow from  
10 the alternating current system 91 to the alternating current system 92 is suddenly changed due to the malfunction of the direct current power transmission system 95, the output of the power storage equipment 94 is changed in response to the change amount so that  
15 stability of the alternating current system 92 is maintained and the fluctuation of the frequency can be restricted. As the power storage equipment, a secondary battery, SMES, a flywheel, a pumped storage power generating system and the like are applicable.  
20 Furthermore, although the power storage equipment consists of a type of equipment which directly stores the electric energy and a type of equipment which converts the electric energy ~~in~~<sup>to</sup> energy of ~~other~~<sup>another</sup> form and stores the converted energy, either equipment is  
25 applicable so long as electric energy can be inputted or outputted speedily in response to a command.

a  
30 In a case that the alternating current system 93 and the alternating current system 92 belong to different countries or different management bodies, although the location where the power storage equipment 94 is installed is the alternating current system 92, ~~an~~ administration equipment 97 for administering the power storage equipment 94 is

provided, wherein the administration equipment 97  
preliminarily administers the property of energy  
stored in the power storage equipment 94, the license  
to use the converter of the power storage equipment 92  
5 and the like. The administration equipment 97 is set  
such that the alternating current system 93  
preliminarily gives information on the acquisition of  
the right to the administration equipment 97 so that  
the administration equipment 97 can acquire the right  
10 preliminarily. Due to such a setting, at the time of  
emergency such as the shortage of electric energy  
supply to the alternating current system 92 caused by  
the sudden stop of the direct current power  
transmission system 95, the alternating current system  
15 93 can preferentially receive the electric energy  
supply from the power storage equipment 94 by way of  
the direct current power transmission system 96. In  
this case, although it becomes necessary to maintain  
the stability of the alternating current system by  
20 taking measure such as interruption of the load to  
cope with the shortage of electricity power supply,  
the administration equipment 97 is set such that it  
owes the responsibility to transmit the electric power  
of the power storage equipment 94 to the alternating  
25 current system 92 in accordance with the contract  
which is concluded in advance.

Fig. 10 is a view showing an example of the  
construction of the interconnection which connects  
Canada system 51 and Russia system 21 shown in Fig. 1.  
30 These alternating current systems 51, 21 are  
respectively provided with alternating current/direct  
current converters 103, 104 and the alternating  
current/direct current converters 103, 104 are



interconnected by a direct current power transmission line 105. The alternating current/direct current converters 103, 104 are respectively controlled by converter control equipment 106, 107. The voltage and current values of the alternating current side and the direct current side of the converter 103 of the alternating current system 51 are converted to signals such as an alternating current electric power detected value  $P_{ac1}$ , an alternating current voltage value  $V_{ac1}$ , a direct current electric power detected value  $P_{dc1}$ , a direct current voltage value  $V_{dc1}$  and the like at a P, V detecting part 108. Information including these values and a trigger angle command value  $\alpha 1$  transmitted from the converter control equipment 106 is transmitted to the converter control equipment 107 at the opposite end by way of communication equipment 10a, 10b. The transaction of information between the communication equipment 10a, 10b is carried out by the satellite communication by way of a communication satellite 10g, ~~an~~ optical communication by way of optical cables, ~~a~~ microwave communication or a telephone circuit.

Furthermore, the alternating current systems 101, 102 are respectively provided with GPS time information acquisition equipment 10e, 10f which can obtain time information from GPS (~~abbreviation of~~ Global Positioning System, which is a wide area position measuring system). The GPS time information acquisition equipment 10e, 10f <sup>prepares</sup> ~~prepare~~ data by adding the time information obtained from the GPS to the information such as alternating current power detected value at respective time cross sections. By transmitting data to which this time information is

added, the converter control equipment 106, 107 at the  
opposite end and the like can grasp the time delay  
incurred by transmission and can carry out the control  
while synchronizing. Furthermore, when the telephone  
5 circuit is used, not only information can be  
transmitted in a digital data mode by way of a modem  
but also information may be transacted such that  
operators of respective converters converse in voice  
by way of telephones. When the languages used become  
10 different because of the difference in countries where  
the converters 106, 107 are installed, language  
translation parts 10c, 10d may be provided between the  
communication equipment 10a, 10b. Although generally  
the language translation parts 10c, 10d may be  
15 constructed by translation machines, men can carry out  
the translation work. In this manner, in the direct  
current interconnection of a long distance which  
extends between the ~~Asia~~<sup>Asian</sup> and American Continents, with  
the provision of a plural information transmission  
20 methods considering the time lag, not only the highly  
reliable power interchange becomes possible but also  
the selection of the inexpensive information  
transmission method becomes possible.

Fig. 11 shows an example where Russia system 21,  
25 Far East system 22, Japan system 24 and China system  
23 are respectively interconnected by direct current  
power transmission systems 11a, 11b, 11c, 11d, 11e and  
11f, for example. When the direct current system 11c  
is stopped for example, the direct current power  
30 transmission systems are respectively controlled such  
that the respective interchanged power of the direct  
current power transmission systems 11a, 11b, 11e and  
11f are increased so as not to change the power



connected by interconnection lines for example. Here,  
the system 23 is provided with ~~a~~ power generating  
equipment 12c and ~~a~~ power storage equipment 126 which  
make the system 23 take the balance between the supply  
and demand of electric energy within the system 23.  
The system 23 is also provided with facilities which  
set the maximum output of the power storage equipment  
126 and the maximum output of the power generating  
equipment 12c greater than the maximum value of the  
load 12f. As a result, even when the interchange from  
other alternating current system 22 becomes impossible  
due to a failure of the direct current power  
transmission system, the balance of supply and demand  
of electric energy in the alternating current system  
23 can be maintained. Furthermore, for enhancing the  
reliability of the electricity power supply, even when  
the transaction of power between the alternating  
current system 23 and the other alternating current  
system 22 or the system 122 suddenly becomes  
impossible, the input and output and the stored amount  
of the power storage equipment 126 and the ~~an~~ excess  
power of the power generating equipment 12c are  
ensured so that the balance of supply and demand of  
the electric energy can be maintained within the  
system 23. Furthermore, when the reliability is  
ensured with respect to the supply of electricity from  
the system 22 to the system 23 by way of the direct  
current power transmission system 127 for example,  
even if the transmission and receiving of power  
between the system 122 and the system 23 <sup>are</sup> ~~is~~ stopped,  
the input and output and the stored amount of the  
power storage equipment 126 and the an excess power of

the power generating equipment 12c are ensured.  
Furthermore, at the time of emergency such as a sudden  
stop of the direct current power transmission systems  
127, 128, instead of carrying out the transaction of  
5 electric energy between the system 22 and the system  
23 for example, other energy such as gas or petroleum  
is transacted, thus enabling the transmitting and  
receiving of energy which meets the preliminarily  
concluded contract.

10 Fig. 13 is a flow chart which shows measures to  
maintain the reliability on the electric energy supply  
within the system 23 shown in Fig. 12. In accordance  
with steps 131, 133, the interchangeable power amount  
from the systems 22, 122 is calculated and the real-  
15 time interchanged power amount from the systems 22,  
122<sup>15</sup> are respectively detected at steps 132, 134.  
Besides these steps, the load amount, the power  
generating amount and the excess generating power of  
the system 23 are detected at steps 135, 136, 137.  
20 Using ~~these~~<sup>this</sup> information, the operating condition of  
the generator, the operating condition of the power  
storage equipment and the interchange amount through  
the direct current power transmission systems 127, 128  
are detected at a step 138. To be more specific, the  
25 respective command values are set such that when the  
direct current power transmission system 127 is  
stopped and the electric power interchanged from the  
system 22 to the system 23 is reduced, the electric  
power which makes up for the reduced amount of  
30 electric power is interchanged from the excess  
generator power, the power storage equipment and the  
alternating current system 122. In this example,  
although the interchange amount of direct current

power transmission system is decided, instead of this,  
the same control can be carried out by changing the  
interchange amount contract of the alternating current  
system at the opposite end of the direct current power  
transmission system.

Fig. 14 is a flow chart which shows one example  
of a method in which <sup>the</sup> Japan system purchases electric  
power from <sup>another</sup> ~~other~~ system by way of the interconnection  
line. The method aims at minimizing ~~of~~ the cost and

Fig. 14 shows the flow for deciding the most suitable  
electric power purchasing pattern. In this example,  
information 141 on exchange rate, information 142 on  
the power generation cost of other systems,

information 143 on alternating and direct current  
power transmission <sup>routes</sup> ~~route~~ for transmitting purchased  
electric energy and the like are <sup>periodically and frequently</sup> ~~obtained~~ using

Internet information or direct transmission means  
~~every seconds~~. Based on <sup>this</sup> ~~these~~ information, at a step  
144, a formulated optimization problem is solved using

the overall cost including the power generation cost  
and power transmission cost as an object function so  
that the optimum power purchasing pattern can be  
decided. Based on the calculated optimum power

purchasing pattern, at a step 145, the interchange  
amount of the direct current power transmission system  
of the interconnection line can be calculated. In

this example, although the minimizing of the cost is  
used as the object function, it may be possible to  
obtain the information on CO<sub>2</sub> emission amount and to

decide the power purchasing pattern while including  
minimizing of CO<sub>2</sub> emission amount or the like into the  
object function. Besides these, balancing of the load  
of the Asia-Pacific rim as a whole, the degree of

a balance between transmitting and receiving, <sup>or</sup> the reliability of the power supply may be set as the object function.

Fig. 15 is a view showing one example of the method for controlling of electric energy  
interchanged using the direct current when remote areas such as Canada system 51 and Russia system 21 and the like shown in Fig. 1 are interconnected by a direct current power transmission system 15b which includes converters 158, 159 and a direct current circuit 15a. An interchanged power control equipment 153 which decides the electric energy interchanged by way of the direct current power transmission system 15b gives the control command values to respective converter control equipment 156, 157. In this case, as means for transmitting information from the interchanged power control equipment 153 to respective converter control equipment 156, 157, if one information transmitting means includes an optical cable 15d while the other information transmitting means is a satellite communication by way of a satellite 15c, this gives rise to a difference in their transmission times. In this case, to make the commands reach both converter control equipment 156, 157 simultaneously, delay timers 154, 155 are respectively mounted on respective information paths.

Furthermore, Fig. 16 is a view showing one example of the construction which measures the delay of the transmission paths in Fig. 15. The converter control equipment 156, 157 respectively send information which is produced by adding time information to signals having synchronism such as GPS obtained by GPS time detecting equipment 161, 162 to a

transmission time detection part 163 located in the vicinity of an interchanged power control equipment 164 by way of a satellite communication transmission path which uses the optical cable 15d and the satellite 15c. Since the times necessary for transmitting information from respective converter control equipment 156, 157 to the transmission time detecting part 163 and the interchanged power control equipment 164 are the same, the transmission time detection part 163 extracts time information from information transmitted and transmission time difference of a plurality of transmission routes is detected. By passing the information on transmission time difference to the interchanged power control equipment 164, it becomes possible to decide the set values of the delay timers 154, 155 of Fig. 15.

In countries like Japan where energy sources such as petroleum, coal and natural gas is scarce, it is the reality that energy sources are daily transported on the surface from countries with enough energy sources. For example, in case of liquefied petroleum gas, in 1994, out of the total import amount, 44 % is imported from Indonesia, 18 % is imported from Malaysia and 15 % is imported from Australia. Using the Asia-Pacific power network of this embodiment, in place of shipping, Japan can receive the energy supply constantly. The transport of the liquefied natural gas with tankers is the distributed transmission (bucket type), whereas the Asia-Pacific power network can transport continuously.

As has been explained heretofore, according to the present invention, with the provision of the power interchange in the wide area making use of the time



difference and the regional difference particularly, <sup>the</sup> following effects (1) - (4) can be achieved, wherein the effect (1) enables the preservation of global environment through reduction of CO<sub>2</sub> and saving of <sup>sources,</sup> ~~sources~~ the effect (2) ensures the balance of power supply and demand and the stable power supply, the effect (3) supports the large power demand which may be necessary in China, and the effect (4) activates the economy of <sup>APREC</sup> ~~APEC~~ countries.

[illegible]